IMAGE CAPTURE AND IDENTIFICATION SYSTEM AND PROCESS

Field of Invention

The invention relates an identification method and process for objects from digitally captured images thereof that uses image characteristics to identify an object from a plurality of objects in a database.

Background of the Invention

There is a need to identify an object that has been digitally captured from a database of images without requiring modification or disfiguring of the object. Examples include:

identifying pictures or other art in a large museum, where it is desired to provide additional information about objects in the museum by means of a mobile display so that the museum so that the objects of interest in the museum are not hidden or crowded out by signs or computer screens;

establishing a communications link with a machine by merely taking a visual image of the machine; and

calculating the position and orientation of an object based on the appearance of the object in an image despite shadows, reflections, partial obscuration, and variations in viewing geometry, or other obstructions to obtaining a complete image. Image capture hardware such as a portable telephones with digital cameras included are now coming on the market and it is desirable that they be useful for duties other than picture taking for transmission to a remote location. It is also desirable that any identification system uses available computing power efficiently so that the computing required for such identification can be performed locally, shared with an Internet connected computer or performed remotely, depending on the database size and the available computing power. In addition, it is desirable that any such identification system can use existing identification markings such as barcodes, special targets, or written language

when such is available to speed up searches and image information retrieval.

Summary of the Invention

The present invention solves the above stated needs. Once an image is captured digitally, a search of the image determines whether symbolic content is included in the image. If so the symbol is decoded and communication is opened with the proper database, usually using the Internet, wherein the best match for the symbol is returned. In some instances, a symbol may be detected, but non-ambiguous identification is not possible. In that case and when a symbolic image can not be detected, the image is decomposed through identification algorithms where unique characteristics of the image are determined. These characteristics are then used to provide the best match or matches in the data base, the "best" determination being assisted by the partial symbolic information, if that is available.

Therefore the present invention provides technology and processes that can accommodate linking objects and images to information via a network such as the Internet, which requires no modification to the linked object. Traditional methods for linking objects to digital information, including applying a barcode, radio or optical transceiver or transmitter, or some other means of identification to the object, or modifying the image or object so as to encode detectable information in it, are not required because the image or object can be identified solely by its visual appearance. The users or devices may even interact with objects by "linking" to them. For example, a user may link to a vending machine by "pointing and clicking" on it. His device would be connected over the Internet to the company that owns the vending machine. The company would in turn establish a connection to the vending machine, and thus the user would have a communication channel established with the vending machine and could interact with it.

The decomposition algorithms of the present invention allow fast and reliable detection and recognition of images and/or

image processing can be implemented in a parallel computing manner, thus facilitating scaling of the system with respect to database size and input traffic loading.

5 Therefore, it is an object of the present invention to provide a system and process for identifying digitally captured images without requiring modification to the object.

Another object is to use digital capture devices in ways never contemplated by their manufacturer.

Another object is to allow identification of objects from 10 partial views of the object.

Another object is to provide communication means with operative devices without requiring a public connection therewith.

These and other objects and advantages of the present invention will become apparent to those skilled in the art after considering the following detailed specification, together with the accompanying drawings wherein:

Brief Description of the Drawings

Figure 1 is a schematic block diagram top-level algorithm 20 flowchart;

Figure 2 is an idealized view of image capture;

Figures 3A and 3B are a schematic block diagram of process details of the present invention.

25 ## Detailed Description of the Preferred Embodiments

The present invention includes a novel process whereby information such as Internet content is presented to a user, based solely on a remotely acquired image of a physical object. Although coded information can be included in the remotely 30 acquired image, it is not required since no additional information about a physical object, other than its image, needs to be encoded in the linked object. There is no need for any additional code or device, radio, optical or otherwise, to be embedded in or affixed to the object. Image-linked objects can be located and identified 35 within user-acquired imagery solely by means of digital image processing, with the address of pertinent information being returned to the device used to acquire the image and perform the

objects based on their visual appearance in an image, no matter whether shadows, reflections, partial obscuration, and variations in viewing geometry are present. As stated above, the present invention also can detect, decode, and identify images and objects based on traditional symbols which may appear on the object, such as alphanumeric characters, barcodes, or 2-dimensional matrix codes.

When a particular object is identified, the position and orientation of an object with respect to the user at the time the image was captured can be determined based on the appearance of the object in an image. This can be the location and/or identity of people scanned by multiple cameras in a security system, a passive locator system more accurate than GPS or usable in areas where GPS signals cannot be received, the location of specific vehicles without requiring a transmission from the vehicle, and many other uses.

When the present invention is incorporated into a mobile device, such as a portable telephone, the user of the device can link to images and objects in his or her environment by pointing the device at the object of interest, then "pointing and clicking" to capture an image. Thereafter, the device transmits the image to another computer ("Server"), wherein the image is analyzed and the object or image of interest is detected and recognized. Then the network address of information corresponding to that object is transmitted from the ("Server") back to the mobile device, allowing the mobile device to access information using the network address so that only a portion of the information concerning the object need be stored in the systems database.

Some or all of the image processing, including image/object detection and/or decoding of symbols detected in the image may be distributed arbitrarily between the mobile (Client) device and the Server. In other words, some processing may be performed in the Client device and some in the Server, without specification of which particular processing is performed in each, or all processing may be performed on one platform or the other, or the platforms may be combined so that there is only one platform. The

link. This process is robust against digital image noise and corruption (as can result from lossy image compression/decompression), perspective error, rotation, translation, scale differences, illumination variations caused by different lighting sources, and partial obscuration of the target that results from shadowing, reflection or blockage.

Many different variations on machine vision "target location and identification" exist in the current art. However, they all tend to provide optimal solutions for an arbitrarily restricted search space. At the heart of the present invention is a high-speed image matching engine that returns unambiguous matches to target objects contained in a wide variety of potential input images. This unique approach to image matching takes advantage of the fact that at least some portion of the target object will be found in the user-acquired image. The parallel image comparison processes embodied in the present search technique are, when taken together, unique to the process. Further, additional refinement of the process, with the inclusion of more and/or different decomposition-parameterization functions, utilized within the overall structure of the search loops is not restricted. The detailed process is described in the following.igure 1 shows the overall processing flow and steps. These steps are described in further detail in the following sections.

For image capture 10, the User 12 (Figure 2) utilizes a computer, mobile telephone, personal digital assistant, or other similar device 14 equipped with an image sensor (such as a CCD or CMOS digital camera). The User 12 aligns the sensor of the image capture device 14 with the object 16 of interest. The linking process is then initiated by suitable means including: the User 12 pressing a button on the device 14 or sensor; by the software in the device 14 automatically recognizing that an image is to be acquired; by User voice command; or by any other appropriate means. The device 14 captures a digital image 18 of the scene at which it is pointed. This image 18 is represented as three separate 2-D matrices of pixels, corresponding to the raw RGB (Red, Green, Blue) representation of the input image. For the purposes of standardizing the analytical processes in this

embodiment, if the device 14 supplies an image in other than RGB format, a transformation to RGB is accomplished. These analyses could be carried out in any standard color format, should the need arise.

5   If the server 20 is physically separate from the device 14, then user acquired images are transmitted from the device 14 to the Image Processor/Server 20 using a conventional digital network or wireless network means. If the image 18 has been compressed (e.g. via lossy JPEG DCT) in a manner that introduces compression

10   artifacts into the reconstructed image 18, these artifacts may be partially removed by, for example, applying a conventional despeckle filter to the reconstructed image prior to additional processing.

The Image Type Determination 26 is accomplished with a discriminator algorithm which operates on the input image 18 and determines whether the input image contains recognizable symbols, such as barcodes, matrix codes, or alphanumeric characters. If such symbols are found, the image 18 is sent to the Decode Symbol 28 process. Depending on the confidence level with which the

20   discriminator algorithm finds the symbols, the image 18 also may or alternatively contain an object of interest and may therefore also or alternatively be sent to the Object Image branch of the process flow. For example, if an input image 18 contains both a barcode and an object, depending on the clarity with which the

25   barcode is detected, the image may be analyzed by both the Object Image and Symbolic Image branches, and that branch which has the highest success in identification will be used to identify and link from the object.

The image is analyzed to determine the location, size, and

30   nature of the symbols in the Decode Symbol 28. The symbols are analyzed according to their type, and their content information is extracted. For example, barcodes and alphanumeric characters will result in numerical and/or text information.

For object images, the present invention performs a

35   "decomposition", in the Input Image Decomposition 34, of a high-resolution input image into several different types of quantifiable salient parameters. This allows for multiple

independent convergent search processes of the database to occur in parallel, which greatly improves image match speed and match robustness in the Database Matching 36. The Best Match 38 from either the Decode Symbol 28, or the inage Database Matching 36, or
5   both, is then determined. If a specific URL (or other online address) is associated with the image, then an URL Lookup 40 is performed and the Internet address is returned by the URL Return 42.

The overall flow of the Input Image Decomposition process is
10   as follows:

        Radiometric Correction
        Segmentation
        Segment Group Generation
        FOR each segment group
                Bounding Box Generation
                Geometric Normalization
                Wavelet Decomposition
                Color Cube Decomposition
                Shape Decomposition
20   Low-Resolution Grayscale Image Generation
        FOR END

Each of the above steps is explained in further detail below. For Radiometric Correction, the input image typically is
25   transformed to an 8-bit per color plane, RGB representation. The RGB image is radiometrically normalized in all three channels. This normalization is accomplished by linear gain and offset transformations that result in the pixel values within each color channel spanning a full 8-bit dynamic range (256 possible discrete
30   values). An 8-bit dynamic range is adequate but, of course, as optical capture devices produce higher resolution images and computers get faster and memory gets cheaper, higher bit dynamic ranges, such as 16-bit, 32-bit or more may be used.

For Segmentation, the radiometrically normalized RGB image is
35   analyzed for "segments," or regions of similar color, i.e. near equal pixel values for red, green, and blue. These segments are defined by their boundaries, which consist of sets of (x, y) point pairs. A map of segment boundaries is produced, which is maintained separately from the RGB input image and is formatted as
40   an x, y binary image map of the same aspect ratio as the RGB image.

For Segment Group Generation, the segments are grouped into all possible combinations. These groups are known as "segment groups" and represent all possible potential images or objects of interest in the input image. The segment groups are sorted based on the order in which they will be evaluated. Various evaluation order schemes are possible. The particular embodiment explained herein utilizes the following "center-out" scheme: The first segment group comprises only the segment that includes the center of the image. The next segment group comprises the previous segment plus the segment which is the largest (in number of pixels) and which is adjacent to (touching) the previous segment group. Additional segments are added using the segment criteria above until no segments remain. Each step, in which a new segment is added, creates a new and unique segment group.

For Bounding Box Generation, the elliptical major axis of the segment group under consideration (the major axis of an ellipse just large enough to contain the entire segment group) is computed. Then a rectangle is constructed within the image coordinate system, with long sides parallel to the elliptical major axis, of a size just large enough to completely contain every pixel in the segment group.

For Geometric Normalization, a copy of the input image is modified such that all pixels not included in the segment group under consideration are set to mid-level gray. The result is then resampled and mapped into a "standard aspect" output test image space such that the corners of the bounding box are mapped into the corners of the output test image. The standard aspect is the same size and aspect ratio as the Reference images used to create the database.

For Wavelet Decomposition, a grayscale representation of the full-color image is produced from the geometrically normalized image that resulted from the Geometric Normalization step. The following procedure is used to derive the grayscale representation. Reduce the three color planes into one grayscale image by proportionately adding each R, G, and B pixel of the standard corrected color image using the following formula:

$$L_{x,y} = 0.34*R_{x,y} + 0.55*G_{x,y} + 0.11*B_{x,y}$$

then round to nearest integer value. Truncate at 0 and 255, if necessary. The resulting matrix L is a standard grayscale image. This grayscale representation is at the same spatial resolution as the full color image, with an 8-bit dynamic range. A multi-resolution Wavelet Decomposition of the grayscale image is performed, yielding wavelet coefficients for several scale factors. The Wavelet coefficients at various scales are ranked according to their weight within the image.

For Color Cube Decomposition, an image segmentation is performed (see "Segmentation" above), on the RGB image that results from Geometric Normalization. Then the RGB image is transformed to a normalized Intensity, In-phase and Quadrature-phase color image (YIQ). The segment map is used to identify the principal color regions of the image, since each segment boundary encloses pixels of similar color. The average Y, I, and Q values of each segment, and their individual component standard deviations, are computed. The following set of parameters result, representing the colors, color variation, and size for each segment:

Y_{avg} = Average Intensity

I_{avg} = Average In-phase

Q_{avg} = Average Quadrature

Y_{sigma} = Intensity standard deviation

I_{sigma} = In-phase standard deviation

Q_{sigma} = Quadrature standard deviation

N_{pixels} = number of pixels in the segment

The parameters comprise a representation of the color intensity and variation in each segment. When taken together for all segments in a segment group, these parameters comprise points (or more accurately, regions, if the standard deviations are taken into account) in a three-dimensional color space and describe the intensity and variation of color in the segment group.

For Shape Decomposition, the map resulting from the segmentation performed in the Color Cube Generation step is used and the segment group is evaluated to extract the group outer edge boundary, the total area enclosed by the boundary, and its area

centroid. Additionally, the net ellipticity (semi-major axis divided by semi-minor axis of the closest fit ellipse to the group) is determined.

For Low-Resolution Grayscale Image Generation, the full-resolution grayscale representation of the image that was derived in the Wavelet Generation step is now subsampled by a factor in both x and y directions. For the example of this embodiment, a 3:1 subsampling is assumed. The subsampled image is produced by weighted averaging of pixels within each 3x3 cell. The result is contrast binned, by reducing the number of discrete values assignable to each pixel based upon substituting a "binned average" value for all pixels that fall within a discrete (TBD) number of brightness bins.

The above discussion of the particular decomposition methods incorporated into this embodiment are not intended to indicate that more, or alternate, decomposition methods may not also be employed within the context of this invention.

In other words:

FOR each input image segment group
    FOR each database object
        FOR each view of this object
            FOR each segment group in this view of this database object
                Shape Comparison
                Grayscale Comparison
                Wavelet Comparison
                Color Cube Comparison
                Calculate Combined Match Score
            END FOR
        END FOR
    END FOR
END FOR

Each of the above steps is explained in further detail below.

FOR each input image segment group

This loop considers each combination of segment groups in the input image, in the order in which they were sorted in the "Segment Group Generation" step. Each segment group, as it is considered, is a candidate for the object of interest in the image, and it is compared against database objects using various tests.

One favored implementation, of many possible, for the order in which the segment groups are considered within this loop is the "center-out" approach mentioned previously in the "Segment Group Generation" section. This scheme considers segment groups in a sequence that represents the addition of adjacent segments to the group, starting at the center of the image. In this scheme, each new group that is considered comprises the previous group plus one additional adjacent image segment. The new group is compared against the database. If the new group results in a higher database matching score than the previous group, then new group is retained. If the new group has a lower matching score then the previous group, then it is discarded and the loop starts again. If a particular segment group results in a match score which is extremely high, then this is considered to be an exact match and no further searching is warranted; in this case the current group and matching database group are selected as the match and this loop is exited.

25 <u>FOR each database object</u>

This loop considers each object in the database for comparison against the current input segment group.

<u>FOR each view of this object</u>

30 This loop considers each view of the current database object, for comparison against the current input segment group. The database contains, for each object, multiple views from different viewing angles.

35 <u>FOR each segment group in this view of this database object</u>

This loop considers each combination of segment groups in the current view of the database object. These segment groups were created in the same manner as the input image segment groups.

Shape Comparison

Inputs:

For the input image and all database images:

I. Segment group outline

II. Segment group area

III. Segment group centroid location

IV. Segment group bounding ellipse ellipticity

Algorithm:

V. Identify those database segment groups with an area approximately equal to that of the input segment group, within TBD limits, and calculate an area matching score for each of these "matches."

VI. Within the set of matches identified in the previous step, identify those database segment groups with an ellipticity approximately equal to that of the input segment group, within TBD limits, and calculate an ellipticity position matching score for each of these "matches."

VII. Within the set of matches identified in the previous step, identify those database segment groups with a centroid position approximately equal to that of the input segment group, within TBD limits, and calculate a centroid position matching score for each of these "matches."

VIII. Within the set of matches identified in the previous step, identify those database segment groups with an outline shape approximately equal to that of the input segment group, within TBD limits, and calculate an outline matching score for each of these "matches." This is done by comparing the two outlines and analytically determining the extent to which they match.

Note: this algorithm need not necessarily be performed in the order of Steps 1 to 4. It could alternatively proceed as follows:

```
FOR each database segment group
    IF the group passes Step 1
        IF the group passes Step 2
            IF the group passes Step 3
                IF the group passes Step 4
                    Successful comparison, save result
                END IF
            END IF
        END IF
    END IF
END FOR
```

Grayscale Comparison

Inputs:

For the input image and all database images:

IX. Low-resolution, normalized, contrast-binned, grayscale image of pixels within segment group bounding box, with pixels outside of the segment group set to a standard background color.

Algorithm:

Given a series of concentric rectangular "tiers" of pixels within the low-resolution images, compare the input image pixel values to those of all database images. Calculate a matching score for each comparison and identify those database images with matching scores within TBD limits, as follows:

```
FOR each database image
    FOR each tier, starting with the innermost and
    progressing to the outermost
        Compare the pixel values between the input and
        database image
```

Calculate an aggregate matching score

IF matching score is greater than some TBD limit
(i.e., close match)

Successful comparison, save result

5   END IF

END FOR

END FOR

Wavelet Comparison

10 Inputs:

For the input image and all database images:

X.   Wavelet coefficients from high-resolution grayscale
image within segment group bounding box.

Algorithm:

Successively compare the wavelet coefficients of the input
segment group image and each database segment group image,
starting with the lowest-order coefficients and progressing
to the highest order coefficients. For each comparison,
compute a matching score. For each new coefficient, only
consider those database groups that had matching scores, at
the previous (next lower order) coefficient within TBD
limits.

25   FOR each database image

IF input image C_0 equals database image C_0 within TBD
limit

IF input image C_1 equals database image C_1 within
TBD limit

30   ...

IF input image C_N equals database image C_N
within TBD limit

Close match, save result and match score

END IF

35   ...

END IF

END IF

END FOR

Notes:

I. "C_i" are the wavelet coefficients, with C_0 being the lowest order coefficient and C_N being the highest.

II. When the coefficients are compared, they are actually compared on a statistical (e.g. Gaussian) basis, rather than an arithmetic difference.

III. Data indexing techniques are used to allow direct fast access to database images according to their C_i values. This allows the algorithm to successively narrow the portions of the database of interest as it proceeds from the lowest order terms to the highest.

Color Cube Comparison

Inputs:

[Y_{avg}, I_{avg}, Q_{avg}, Ysigma, I_{sigma}, Q_{sigma}, Npixels] data sets ("Color Cube Points") for each segment in:
    I.   The input segment group image
    II.   Each database segment group image

Algorithm:
    FOR each database image
      FOR each segment group in the database image
        FOR each Color Cube Point in database segment group, in order of descending Npixels value
          IF Gaussian match between input (Y,I,Q) and database (Y,I,Q)
            I.   Calculate match score for this segment
            II.   Accumulate segment match score into aggregate match score for segment group
            III. IF aggregate matching score is greater than some TBD limit (i.e., close match)
                Successful comparison, save result
          END IF
        END FOR

END FOR

END FOR

Notes:

I.   The size of the Gaussian envelope about any Y,I,Q point is determined by RSS of standard deviations of Y, I, and Q for that point.

Calculate Combined Match Score

The four Object Image comparisons (Shape Comparison, Grayscale Comparison, Wavelet Comparison, Color Cube Comparison) each return a normalized matching score. These are independent assessments of the match of salient features of the input image to database images. To minimize the effect of uncertainties in any single comparison process, and to thus minimize the likelihood of returning a false match, the following root sum of squares relationship is used to combine the results of the individual comparisons into a combined match score for an image:

CurrentMatch = SQRT($W_{oc}M_{oc}^2$+ $W_{ccc}M_{ccc}^2$+ $W_{wc}M_{wc}^2$+ $W_{sgc}M_{sgc}^2$), where Ws are TBD parameter weighting coefficients and Ms are the individual match scores of the four different comparisons.

The unique database search methodology and subsequent object match scoring criteria are novel aspects of the present invention that deserve special attention. Each decomposition of the Reference image and Input image regions represent an independent characterization of salient characteristics of the image. The Wavelet Decomposition, Color Cube Decomposition, Shape Decomposition, and evaluation of a sub-sampled low-resolution Grayscale representation of an input image all produce sets of parameters that describe the image in independent ways. Once all four of these processes are completed on the image to be tested, the parameters provided by each characterization are compared to the results of identical characterizations of the Reference images, which have been previously calculated and stored in the database. These comparisons, or searches, are carried out in parallel. The result of each search is a numerical score that is a weighted measure of the number of salient characteristics that

"match" (i.e. that are statistically equivalent). Near equivalencies are also noted, and are counted in the cumulative score, but at a significantly reduced weighting.

One novel aspect of the database search methodology in the present invention is that not only are these independent searches carried out in parallel, but also, all but the low-resolution grayscale compares are "convergent." By convergent, it is meant that input image parameters are searched sequentially over increasingly smaller subsets of the entire database. The parameter carrying greatest weight from the input image is compared first to find statistical matches and near-matches in all database records. A normalized interim score (e.g., scaled value from zero to one, where one is perfect match and zero is no match) is computed, based on the results of this comparison. The next heaviest weighted parameter from the input image characterization is then searched on only those database records having initial interim scores above a minimum acceptable threshold value. This results in an incremental score that is incorporated into the interim score in a cumulative fashion. Then, subsequent compares of increasingly lesser-weighted parameters are assessed only on those database records that have cumulative interim scores above the same minimum acceptable threshold value in the previous accumulated set of tests.

This search technique results in quick completion of robust matches, and establishes limits on the domain of database elements that will be compared in a subsequent combined match calculation and therefore speeds up the process. The convergent nature of the search in these comparisons yields a ranked subset of the entire database.

The result of each of these database comparisons is a ranking of the match quality of each image, as a function of decomposition search technique. Only those images with final cumulative scores above the acceptable match threshold will be assessed in the next step, a Combined Match Score evaluation.

Four database comparison processes, Shape Comparison, Grayscale Comparison, Wavelet Comparison, and Color Cube Comparison, are performed. These processes may occur

sequentially, but generally are preferably performed in parallel on a parallel computing platform. Each comparison technique searches the entire image database and returns those images that provide the best matches, for the particular algorithm, along with

5   the matching scores for these images. These comparison algorithms are performed on segment groups, with each input image segment group being compared to each segment group for each database image.

Figures 3A and 3B show the process flow within the Database

10   Matching operation. The algorithm is presented here as containing four nested loops with four parallel processes inside the innermost loop. This structure is for presentation and explanation only. The actual implementation, although performing the same operations at the innermost layer, can have a different structure in order to achieve the maximum benefit from processing speed enhancement techniques such as parallel computing and data indexing techniques. It is also important to note that the loop structures can be implemented independently for each inner comparison, rather than the shared approach shown in the Figures

20   3A and 3B.

Preferably, parallel processing is used to divide tasks between multiple CPUs (Central Processing Units) and/or computers. The overall algorithm may be divided in several ways, such as:

Sharing the Outer Loop:	In this technique, all CPUs run the entire algorithm, including the outer loop, but one CPU runs the loop for the first N cycles, another CPU for the second N cycles, all simultaneously.
Sharing the Comparisons:	In this technique, one CPU performs the loop functions. When the comparisons are performed, they are each passed to a separate CPU to be performed in parallel.
Sharing the Database:	This technique entails splitting database searches between CPUs, so that each CPU is

responsible for searching one section of
the database, and the sections are searched
in parallel by multiple CPUs. This is, in
essence, a form of the "Sharing the Outer
Loop" technique described above.

Actual implementations can be some combination of the above
techniques that optimizes the process on the available hardware.
Another technique employed to maximize speed is data
5   indexing. This technique involves using *a priori* knowledge of
where data resides to only search in those parts of the database
that contain potential matches. Various forms of indexing may be
used, such as hash tables, data compartmentalization (i.e., data
within certain value ranges are stored in certain locations), data
sorting, and database table indexing. An example of such
techniques is, in the Shape Comparison algorithm (see below), if a
database is to be searched for an entry with an Area with a value
of A, the algorithm would know which database entries or data
areas have this approximate value and would not need to search the
15   entire database.

Thus, there has been shown novel identification methods and
processes for objects from digitally captured images thereof that
uses image characteristics to identify an object from a plurality
of objects in a database apparatus and which fulfill all of the
20   objects and advantages sought therefor. Many changes,
alterations, modifications and other uses and applications of the
subject invention will become apparent to those skilled in the art
after considering the specification together with the accompanying
drawings. All such changes, alterations and modifications which
25   do not depart from the spirit and scope of the invention are
deemed to be covered by the invention which is limited only by the
claims that follow.